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INVESTIGATIONS IN COSMIC AND GAMMARAY ASTRONOMY

AND NUCLEAR INSTRUMENTS

Comprising Quarterly Reports for March-May, June-August, September-November, 1978, and December 1978-February 1979.

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SUMMARY

Work has continued throughout the reporting period on reduction of data from the Fall 1976 flight of the MSFC-UAH Cosmic Ray Experiment. During this period a major effort was undertaken to improve and rebuild the experiment. This was accomplished and a successful flight was completed in September 1978 from Pierre, South Dakota with the new instrument.

ELEMENTAL FLUXES IN THE COSMIC RAYS: MEASUREMENTS OF SPECTRAL VARIATIONS MADE DURING THE FALL 1976 FLIGHT

The purpose of the flight was to derive accurate flux and energy spectra for beryllium through iron over the limited energy range allowed by the Teflon Cerenkov counter.

Due to a leaky ballon only 17 hours of data were gathered on the flight of which 6 hours were at a relatively constant altitude corresponding to 6 gms/cm^2 or less of overlying atmosphere. Analysis is partially complete on that 6 hours of data and will be reported on here.

During this 6 hours 81,000 events were recorded. 51,000 events gave an acceptable track in a computer track-finding routine, the efficiency of which will be discussed below. Some loose pulse height criteria which were developed by examining individual events were applied to pulse height pairs C1:C2, IC1: IC2 and $\overline{IC}$: S. These criteria eliminated 12,000 events. Trajectory criteria related to the geometrical aperture eliminated another 5,500.

The performance of the MWPC and the track-finding routine exceeded expectations. A visual examination was made of several hundred events. This showed that for $Z \geq 5$ the track finding routine accepted about 4% of events for which a visual examination indicated a shower or interaction. In all such cases in this set the events were later removed by the pulse height criteria. An examination of the file of events rejected by the track routine indicated an upper limit of 1% of lost good events. The predominant events rejected by the routine were showers at the lower end of the charge range. This MWPC hodoscope

thus is a highly efficient track recovery device and constitutes an important feature for achieving accurate flux measurements.

Scatter plots are shown in figure 1-5 of ion chamber versus C1 and C2 pulse heights for the events that survived the criteria mentioned above. Using only this information a charge resolution of 0.6 charge units FWHM over the usable kinetic energy range was obtained for the CNO group. This resolution is expected to improve considerably when the scintillator is mapped and included in the charge assignment.

Using this sample of events, and before further corrections, we derive a C/O ratio of 1.19 at T>560 MeV/n and 1.14 at T>800 MeV/n above the instrument.

Abundance ratios (for example Si/O = 0.153 and S/O = .033 at T>800 MeV/n) and absolute fluxes (see Table 1) are compatible with some accepted values (Juliusson 1974, Ormes et al. 1975, Arens and Ormes 1975).

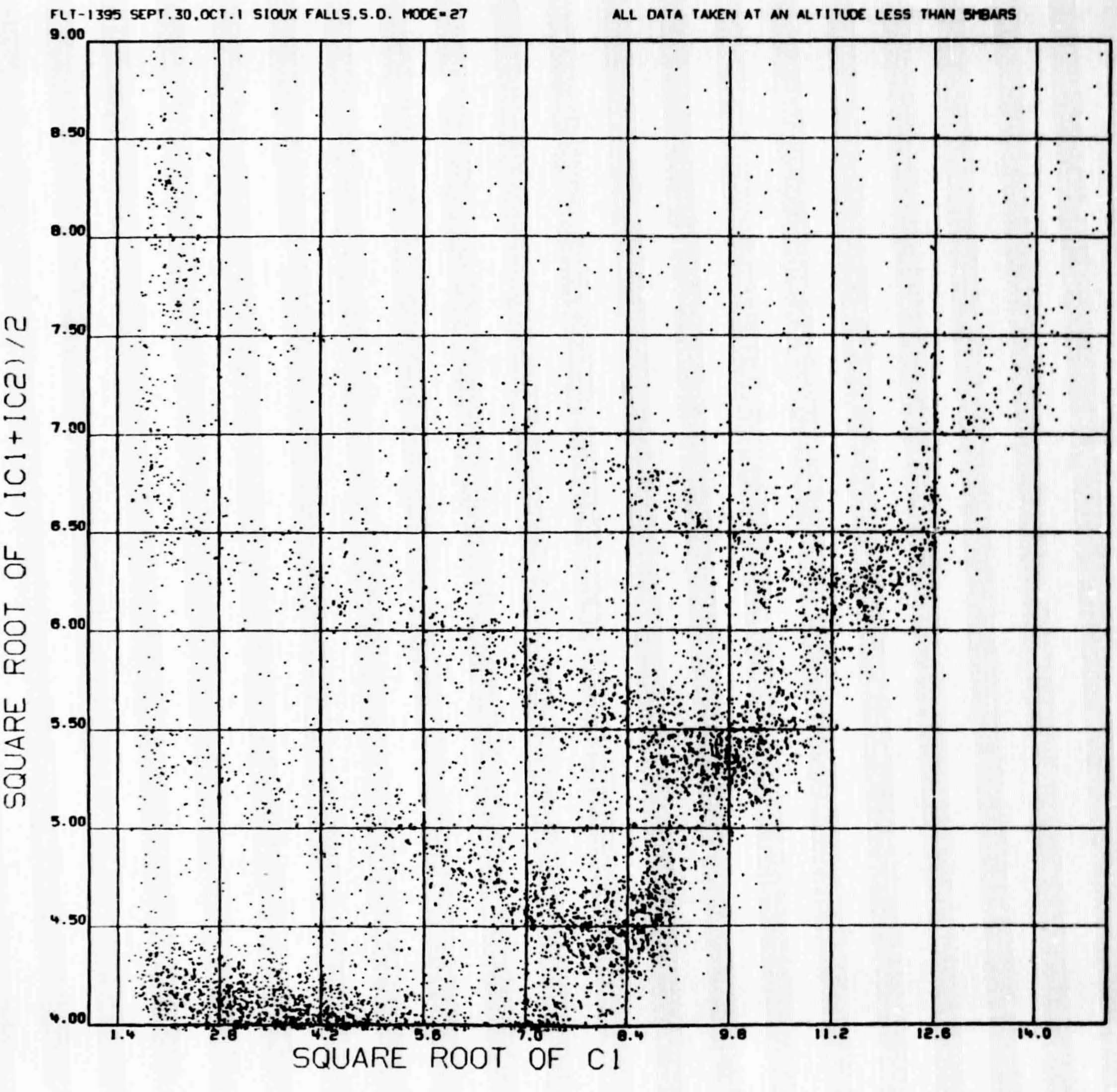
TABLE 1

Preliminary Oxygen Fluxes Above the Instrument

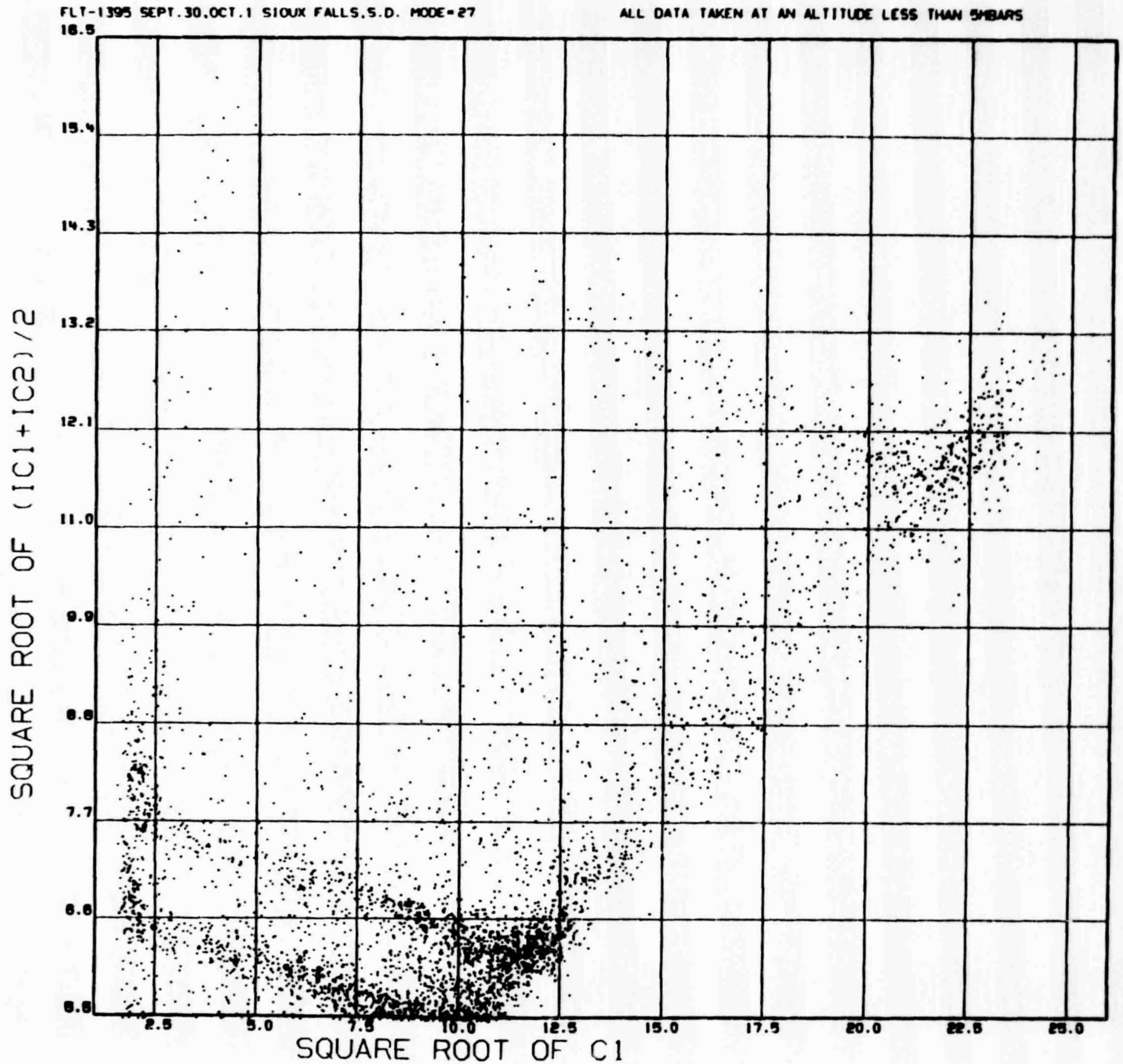
Kinetic Energy	$N_{(o)}$	Flux† (uncorrected)	Flux*	Published
GeV/n	No. detected	$\frac{N_{(o)}}{2530}$ $(m^2 sr\ s)^{-1}$	$(m^2 sr\ s)^{-1}$	Values of Flux
>1.0	5100	2.02	2.5	2.6 [Juliusson 1974; under 6 g cm^{-2} atmosphere]
>.56	7726	3.05	3.8	3.76 [Ormes et al. 1975, Energy at top of atm; Flux at balloon]

† 2530 = geometrical factor x live time

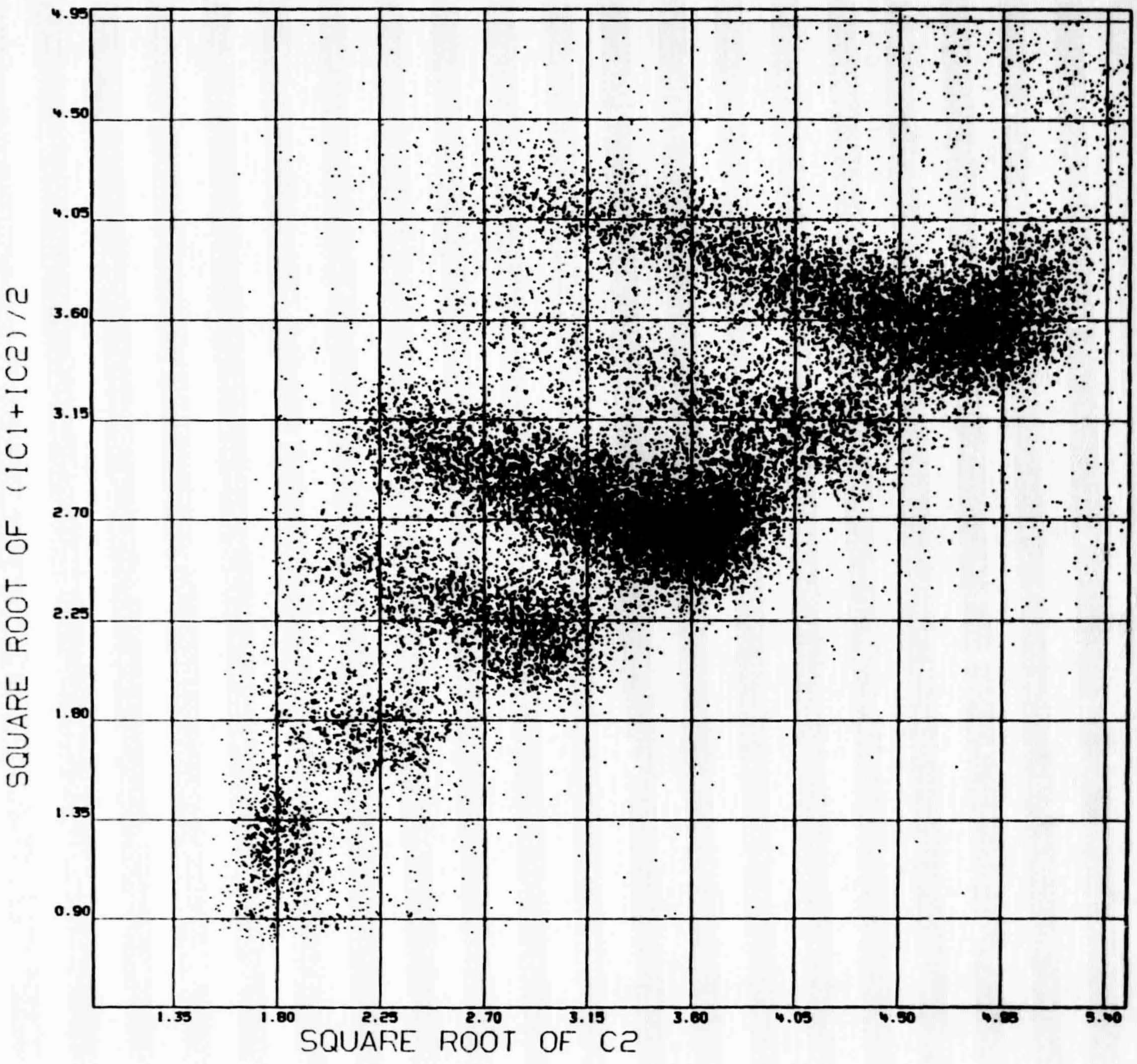
* Integral flux corrected for interactions in the instrument.



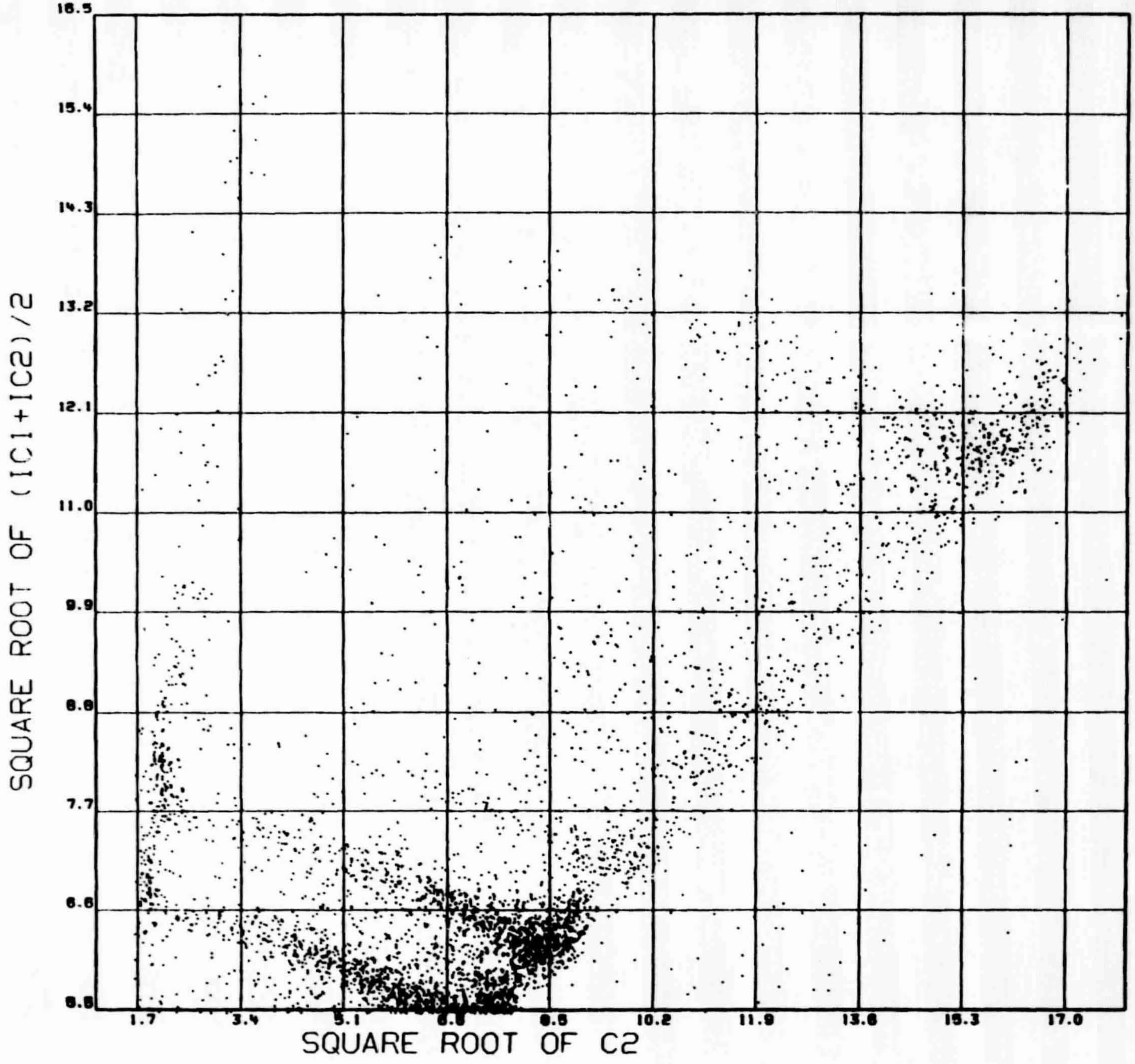
FLT-1395 SEPT.30,OCT.1 SIOUX FALLS,S.D. MODE=27
ALL DATA TAKEN AT AN ALTITUDE LESS THAN 5MBARS
9.00
8.50
8.00
7.50
7.00
6.50
6.00
5.50
5.00
4.50
4.00
1.4
2.8
4.2
5.6
7.0
8.4
9.8
11.2
12.6
14.0
SQUARE ROOT OF C1
SQUARE ROOT OF (IC1+IC2)/2


FLT-1395 SEPT.30,OCT.1 SIOUX FALLS,S.D. MODE=27
ALL DATA TAKEN AT AN ALTITUDE LESS THAN 5MBARS
16.5
15.4
14.3
13.2
12.1
11.0
9.9
8.8
7.7
6.6
5.5
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
SQUARE ROOT OF (IC1+IC2)/2
SQUARE ROOT OF C1

FLT-1395 SEPT.30,OCT.1 SIOUX FALLS,S.D. MODE=27 ALL DATA TAKEN AT AN ALTITUDE LESS THAN 5MBARS

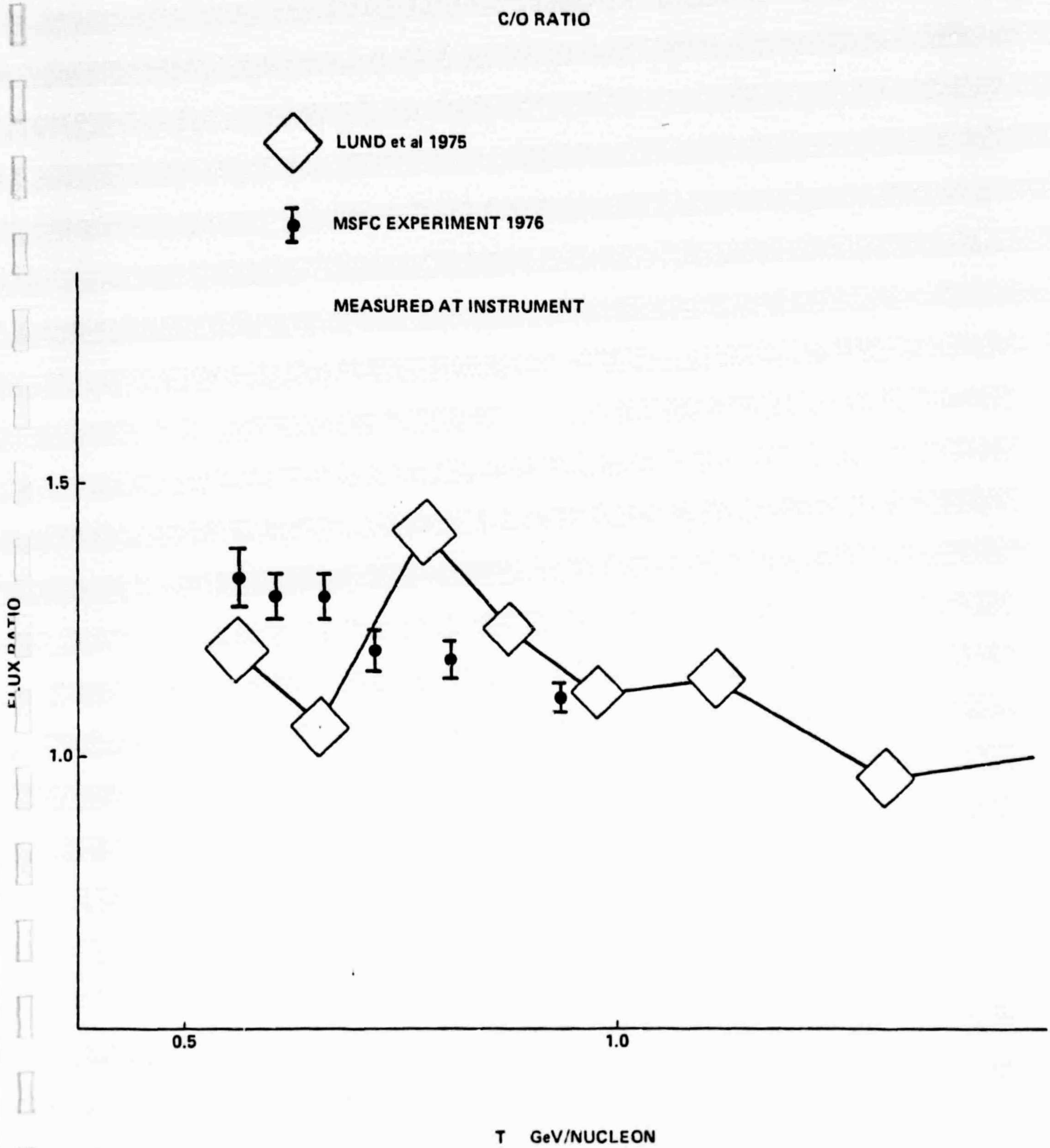


FLT-1395 SEPT.30,OCT.1 SIOUX FALLS,S.D. MODE=27 ALL DATA TAKEN AT AN ALTITUDE LESS THAN 5MBARS



Particle energies are given at the top of the instrument and are calculated from the fiducial point given by the minimum ionizing velocity in the ion chambers. The particle energy is then corrected for slowing in the counter material above the ion chambers.

After completion of atmospheric and instrumental corrections we anticipate sufficient charge and energy resolution in the range of 500 - 1500 MeV/n to derive accurate differential fluxes for the more abundant elements and to comment on recently reported anamolies in some of the abundance ratios (Lund et al. 1975). A plot of the preliminary data on the differential c/o ratio is shown in figure 6.


C/O RATIO
LUND et al 1975
MSFC EXPERIMENT 1976
MEASURED AT INSTRUMENT
FLUX RATIO
1.5
1.0
0.5
1.0
T GeV/NUCLEON

THE FALL 1978 FLIGHT

The scientific objectives of the Fall 1978 flight were two:

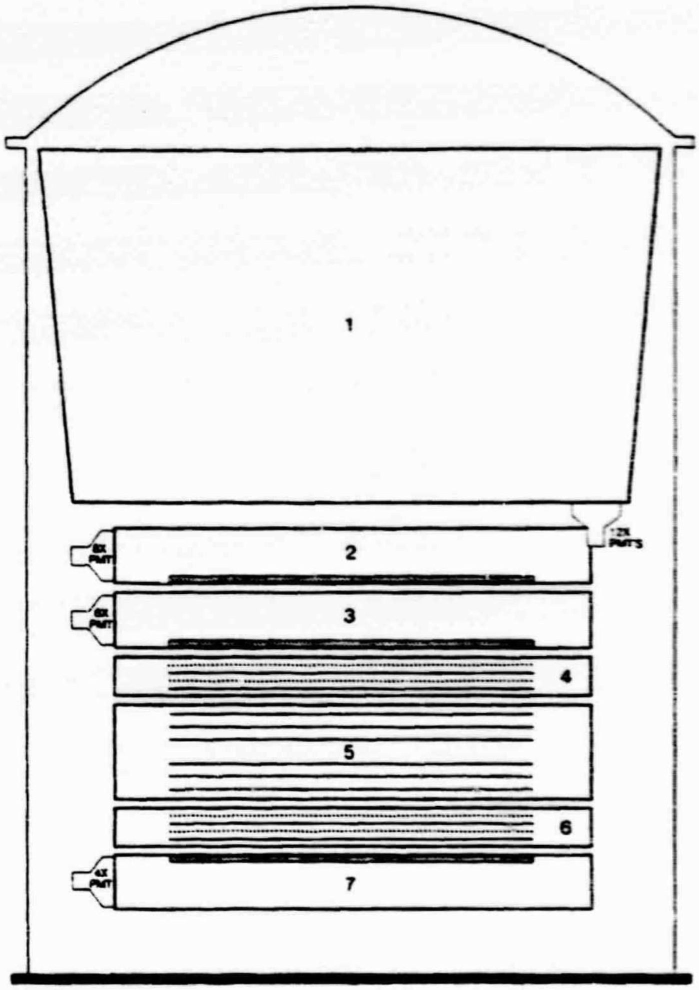
1) To improve the statistical significance of the flux measurement over the energy range 0.5 - 2 GeV/n made during the 1976 flight for elements B to Ni. To achieve measurements of differential fluxes of the rarer elements at least 40 hours was required for our geometrical aperture. Only 17 hours were achieved during the 1976 flight and much of this was at air thicknesses greater than 5 g cm^{-2}.

2) Flux measurements in the range 20-50 GeV/n have been made with most statical significance by the Chicago group. While theirs is a powerful and effective method it relies upon consistency checks between detectors for rejection of showers and nuclear interactions. The MSFC-UAH experiment with a large freon-12 gas Cerenkov counter added is capable of energy measurement in the 20-50 GeV/n region as well as having the distinct advantage of following the particle track through the experiment with the 8-layer MWPC. This has shown itself to be extremely efficient at both selecting clean particle events and rejecting interactions and showers.

The following work was done to bring the instrument to the required condition: the new configuration of detectors is shown in figure 7.

1) Both MWPC modules were opened and all wires and grids checked. Everything appeared in perfect order in spite of 3 attempted launches and 2 actual launches and recoveries in 1976.

MSFC COSMIC RAY BALLOON FLIGHT EXPERIMENT



OBJECTIVES

1 MEASURE RELATIVE ABUNDANCES OF COSMIC RAYS $28 \geq Z \geq 4$ [illegible]0 GeV/n $\geq T \geq 0.$[illegible] GeV/n

2 MEASURE ABSOLUTE FLUX OF COSMIC RAYS FOR $28 \geq Z \geq 4$ AND $T \geq 0.5$ GeV/n

3 DEVELOP INSTRUMENTATION FOR SPACELAB AND THE COSMIC RAY OBSERVATORY

DETECTORS

1 CERENKOV COUNTER, FREON GAS, KINETIC ENERGY $T > 20$ GeV/n

2 CERENKOV COUNTER, TEFLON $2 > T > 0.5$ GeV/n

3 CERENKOV COUNTER, LUCITE
- $0.5 > T > 0.33$ GeV/n
- NUCLEAR CHARGE Z, $T > 0.5$ GeV/n

4 MULTIWIRE PROPORTIONAL COUNTER
- TRAJECTORY,
- REJECT BAD EVENTS

5 DUAL ION CHAMBER (XENON GAS)
- NUCLEAR CHARGE Z
- 20 GeV/n $> T > 2$ GeV/n

6 SAME AS 4

7 PLASTIC SCINTILLATOR, NE102
NUCLEAR CHARGE Z

2) Both Cerenkov detectors were rebuilt with 8 PM tubes instead of 4. Laboratory tests showed that for fast muons about 10-11 photoelectrons were produced per muon for the new Teflon counter compared with about 6 for the previous version.
3) The Lucite (Pilot 425) Cerenkov detector (C_P) pas placed above the gas counter modules (it was below them for the 1976 flight). This takes more advantage of the proportional counters' ability to perceive nuclear interactions within C_P. Also, slowing in C_T is not then so important.
4) The plastic scintillator (NE 102) at the bottom of the stack was a new detector. A diffuse reflecting white box was used with the plastic viewed by 4 three-inch PM tubes instead of the old light-pipe-coupled version. Much better light collection uniformity was obtained.
5) The Freon-12 gas scintillator was an entirely new departure in experimental hardware for us. The design and manufacture was governed strongly by the low weight and cost budget allowed and the very short lead time available. The entire detector, in the form of a section of a right cone 30 inches high and 56 inches across at the base, with 12 five-inch PM tubes was designed and built in the laboratory within 3 months of the launch date.

The detector weighed about 100 lbs. including 50 lbs. for the tubes, bases and shields. It was painted outside with black paint and inside with G.E. Glyptal, followed by a white primer and four coats of Eastman Kodak white reflectance coating. This latter proved to be

inadequate and was later covered with white Millipore paper.

Calculations show Cerenkov light emitted by sea-level muons to be insufficient for calibrating this detector*. However, two sea-level muon checks were devised, one utilising the output of muons in the glass face of a PM tube and lucite window, and the other produced in a 1 inch thick slab of lucite placed in the box. This latter material produced ~750 photons when transitted by a very fast muon. Since most muons detected will not have such high energy a figure of 600 photons was used for estimating collection efficiency. For a conversion efficiency of 15% and a measured distribution width corresponding to ~12 photoelectrons a collection efficiency of ~13% was calculated.

For a carbon particle of energy >50 GeV/n normally incident upon the counter we estimate a yield of 70 photoelectrons. This indicates an error of about 5 GeV/n at 30 GeV/n. The PM tubes are grouped in sets of 6 and connected to separate amplifiers. Coincident pulses from these which are not consistent to a high degree indicate the passage of a knock-on electron through the window of a PM tube. Such an event can severely distort the pulse height associated with the primary event since the windows produce typically 10 times the light output for a $z = 1$ particle in the gas. Collection efficiency for these photons is several times greater also. The track visualisation allowed by the MWPC information provides a powerful means of detecting showers masquerading as primary particle events. Thus when the gas

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* A muon at Cerenkov saturation in the gas produces only 2 photoelectrons in all 12 tubes combined.

Cerenkov tube sets show inconsistency, but the track shows well in the MWPC and the other detectors are consistent, a correction to the gas Cerenkov ADC pulse height may be made. A thorough study is planned of the capabilities of the MWPC and the ion chambers for these high energy (20-100 GeV/n) particles.

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Lund, N., I. L. Rasmussen, B. Peters, and N. J. Westergaard, Proc. 14th. Int. Cosmic Ray Conference (Munich), 1, 257 (1975).

Ormes, J. F., A. Fisher, F. Hagen, R. Maehl, and F. J. Arens, Proc. 14th. Int. Cosmic Ray Conference (Munich), 1, 245 (1975).